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SETTLING-TIME ANALYSIS IN TCP EXPEDITED LTE WIRELESS NETWORK USING MIXED SENSITIVITY CONTROL AND PID CONTROL TECHNIQUE.

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ABSTRACT: There has been increasing demand for faster and more reliable network in recent times. More demanding is a robust system that can adequately maintain good performance with 0% overshoot and ability to withstand disturbances due to traffic congestion and system uncertainties. The problems with LTE networks are Transmission Control Protocol (TCP) low speed implementation, which does not support the requirements of the Long Term Evolution (LTE) network. This work aims at reducing Settling-Time in TCP Expedited LTE wireless Network using Mixed Sensitivity control and PID Control Technique. In addition, to compare the two techniques with the aim of ascertaining the best technique to adopt in the TCP implemented LTE network. LTE network model performance-improvement was carried out using robust control technique like mixed sensitivity synthesis. The desired system response is converted into three adjustable weighting functions to develop a compensation function by mixsyn command. The LTE network improvement was also carried out using PID control technique with three control functions. It was observed that the mixed sensitivity synthesis achieved better performance characteristics with high network average speed of 0.00043 seconds of 0.1 seconds base value, which is 99.57% out of 0.1 seconds for a good system. This result indicates that the mixed sensitivity synthesis will address traffic congestion issue better than the PID control technique.

KEYWORDS: Transmission Control Protocol, Mixsyn, PID, Settling Time, Time Domain.

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Original Article

1.0 INTRODUCTION

With recent development of smart communication devices, there has been increased demand for good quality of service (QoS) and quality of experience (QoE) at low operational cost [1]. This necessitates the requirement for system resources to be efficient with optimal performance and robustness. Based on Ericsson 2017 survey statistics [2], 4G subscribers have grown more than 2.6 billion and around 5.5 billion additional 4G users are expected. That means that by 2022, an exponential growth is expected in the system utility that will overwhelm network functionalities. The Cisco report [3], also indicates that downloading of data transfer and video streaming have contributed immensely to the increase in network traffic in recent years and beyond, and mobile data traffic will increase by more than 47% in 2022 and beyond compared to that of 2017. There has been increased demand for faster and more reliable network in recent times and more demanding is a robust system that can adequately maintain good performance with reduced tracking error, good throughput and ability to withstand disturbances due to traffic congestion and system uncertainties. This work aims to simulating and analyzing the settling rate of a TCP facilitated LTE wireless network using mixsyn and PID control technique. The objective is to compare the response of the system with the sole purpose of ascertaining the best control technique to adopt in an LTE network.

2.0 Review of Related Works

[65] carried out a research work on the efficiency of a PID-based Congestion Control for High-speed IP-networks. They stated that network congestion occurs, when a receiving node is receiving more data than it can handle or forward to an output interface. It leads to significant performance degradation: additional delays and massive packet losses.

[49] Carried out a research on the Design of feedback controller for TCP/AQM networks. They proposed a novel proportional-differential-type feedback controller called Novel-PD as a new active queue management (AQM) to regulate the queue length with small oscillation. This measures the current queue length and uses the current queue length and differential error signals to adjust packet drop probability dynamically. In their work, they considered control theorems in the analysis of TCP/AQM system stability and designed the TCP control by selecting control gain parameters of Novel-PD in order to achieve a system with improved stability. The results in their work show that the REM, RED and PI controller designed methods recorded very high level of oscillations especially at the steady state trajectories of the TCP/AQM controlled networks. These results showed worst performance and unstable TCP/AQM systems. Secondly, in order to surely ascertain robust stability, the analysis of a system designed must be carried out in frequency domain, which provides the means to measure the stability margins. However, the analysis of the system design in their work was carried out in time domain, which does not provide means to measure the stability margin. Therefore, the design in this work lacks characteristics to ensure the best performance and stability of the PD based controller for TCP/AQM network.

[94] They introduced a novel and robust active queue management (AQM) scheme based on a fuzzy controller, called hybrid fuzzy-PID controller. They stated that in the TCP network, AQM is important to regulate the queue length by passing or dropping the packets at the intermediate routers. However, they argued that those algorithms show weaknesses in the detection and control of congestion under dynamically changing network situations.

However, from the results in their work showed that speed of the actual output signal or the actual queue length trajectory is greater than unity and therefore did not attain the speed required for TCP/AQM system over LTE network. The sensitivity measured in their work was not analyzed in frequency domain rather it was analyzed in time domain; therefore, it is difficult to ascertain the real sensitivity behaviors of the various methods of the AQM design applied in their work. With the results in their work, it will be difficult to ascertain the performance of the controlled system. This is because the uncertainty issues were not considered and the robustness specifications were not met.

3.0 METHODOLOGY

Data collection enables the study of the behavior of TCP over LTE network in a high data traffic area. This will help to understand the causes of regular call drops, call hanging or poor call connections that occur in most places.

If the TCP measured time is low, which means that the speed of the TCP over LTE network is low, then the spectrum utilization will be low and such will cause poor performance of the network. It will also increase the error rate, which affects the accuracy and reliability of the network.

Thus the lower the time of packet delivery, the better the network speed.

The base time value (T_B) range for the TCP based LTE network time is: ≤0.1 Seconds and≤0.5 Seconds.

For an averagely good network, T_B must be less than or equal to 0.1 seconds i.e. $T_B \leq 0.1\ seconds$ and for a poor network T_B can be less than or equal to 0.5 seconds i.e.$T_B = 0.5\ seconds$.

The percentage difference was calculated using the model:

$$Percentage\ Deference = \frac{T_B - T}{T_B} \times \frac{100}{1}$$

Where T is the measured time.

3.1 Performance Measurement and Analysis of TCP Over LTE Network Model

The LTE network system is designed to have a high speed of data communication propagation and it requires a reliable data traffic congestion control method such as TCP. Since TCP has a significant limitation in data loss and it is not that fast due to the high error that exists as a result of the difference between the actual transferred signal and the desired transferred signal, it has been criticized in many research works. However, TCP still remains the most reliable network data traffic congestion control method due to its simplicity and data reception acknowledgement capabilities. Therefore, improving the performance and stability becomes necessary to maintain the improved performance in order to withstand congestion disturbances.

In this work, TCP based LTE network was considered and the focus here is to reduce the settling rate to improve the performance of the TCP in terms of the following characteristics:

Data traffic congestion control speed, which is normally reflected in the time domain graph of the transfer function of the TCP/AQM model.

The cross-over frequency ω_c; The cross-over frequency is proportionally inverse to the response time of the system, so it means that to get a faster system, ω_c must be as high as possible [83].

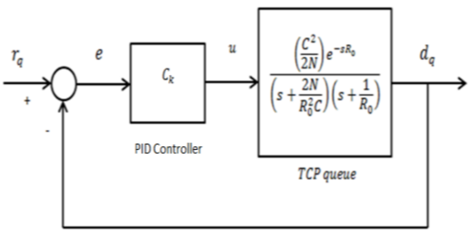

Figure 1: TCP Plant with PID Controller.

Taking into consideration the following dynamics of the TCP queue system:

$$\begin{cases} G_W(s) = \dfrac{\frac{R_0C^2}{2N}}{\left(s+\frac{2N}{R_0^2C}\right)} \\ G_q(s) = \dfrac{\frac{N}{R_0}}{\left(s+\frac{1}{R_0}\right)} \end{cases} \tag{1}$$

where $G_W(s)$represents the TCP's dynamic model without time delay and $G_q(s)$represents the queue dynamic model.

These dynamic models can be demonstrated diagrammatically as shown in Figure 3.1.

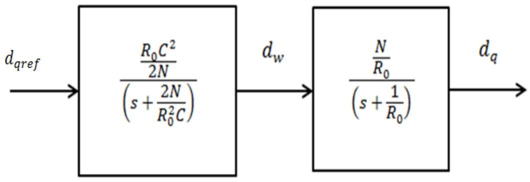

Figure 2: TCP Queue Model Without Time Delay.

The transfer function of the TCP queue without time delay becomes:

$$\frac{d_q}{d_{qref}} = G_W(s).G_q(s) \tag{2}$$

$$\frac{d_q}{d_{qref}} = \frac{\frac{R_0C^2}{2N}}{\left(s+\frac{2N}{R_0^2C}\right)} \cdot \frac{\frac{N}{R_0}}{\left(s+\frac{1}{R_0}\right)} \tag{3}$$

The AQM action can be seen as a compensator that works together with the TCP dynamic in order to improve the performance of the system. Considering the AQM time delay as shown in Figure 1.11 which is one of the essential practical features of the network dynamics that must be captured in the model during the design stage of the network performance optimization, the TCP queue model becomes:

$$\begin{cases} G_W(s) = \dfrac{\frac{R_0C^2}{2N}}{\left(s+\frac{2N}{R_0^2C}\right)} e^{-sR_0} \\ G_q(s) = \dfrac{\frac{N}{R_0}}{\left(s+\frac{1}{R_0}\right)} \end{cases} \tag{4}$$

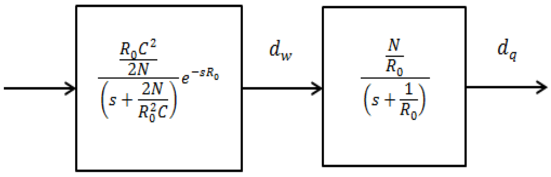

Figure 4: TCP Queue Model with Time Delay

The transfer function becomes:

$$\frac{d_q}{d_{qref}} = \frac{\frac{R_0C^2}{2N}}{\left(s+\frac{2N}{R_0^2C}\right)} e^{-sR_0} \cdot \frac{\frac{N}{R_0}}{\left(s+\frac{1}{R_0}\right)} \tag{5}$$

Solving the differential equation for the function *Gp*(*s*) is the plant transfer function and takes into consideration the queue dynamics (*Gq*(*s*)) and the TCP behavior dynamics (*Ptcp*(*s*)), the following equation was obtained:

$$G_p(s) = \frac{\left(\frac{C^2}{2N}\right)e^{-sR_0}}{\left(s+\frac{2N}{R_0^2C}\right)\left(s+\frac{1}{R_0}\right)} \tag{6}$$

The demonstration of TCP/AQM dynamic model transfer function is shown in Figure 1.12.

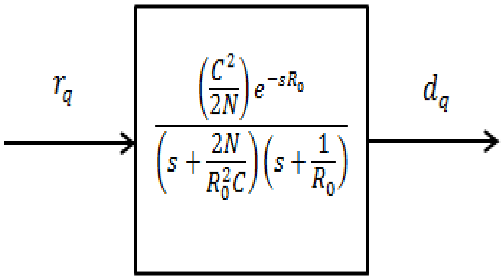

Figure 3: The TCP/AQM Model Plant

Where r_q is the input signal (reference input) into the TCP/AQM system

3.2 Performance Analysis of the TCP model based on the LTE Network

The performance analyses of the TCP system model over LTE network was carried out based on open loop control without an external control technique. The purpose of carrying out these analyses on the existing system model was to study the behavior of the system in order to ascertain the need for an external control technique. The analyses were carried out in two domains, namely: time and frequency domains. These methods of analyses reveal most of the characteristics of the TCP model and provide most needed features to enable better description of the system behavior.

3.2.1 Performance Analysis in Time Domain

The performance analysis of the TCP controlled queue length output characteristics were determined by the trajectory of the queue length graph in time domain. The time-domain graph plots its amplitudes as a function of time. Since the LTE network requires fast and minimized error data transfer and traffic congestion-control mechanism, the TCP model performance analysis was based on the determination of the following characteristics:

- Steady state error and
- Settling time of the input amplitude.

Settling time: This is a critical characteristic of the TCP model. It is focused on the speed of the LTE network systems. The settling time is the time required for the system output to settle within a certain percentage of the input amplitude. This means that the settling time determine the speed of the network during the data transfer and data traffic-congestion control of the system [95,96].

3.2.2 Modified TCP Performance Characteristics Using Mixed Sensitivity Synthesis

The mixed-synthesis involves the use of weighting factors W_1 and W_2 on the TCP queue plant to achieve the desired system performance. It forms the augmented function using the weighting functions and the TCP queue plant. The methods find the value of the controller C_k that can improve the performance of the system through loop shaping which involves the tuning of the weighting functions.

3.2.3 The Mix-Synthesis Algorithm Presented as Follows

- Apply TCP queue transfer function,

$$G_p(s) = \frac{\left(\frac{C^2}{2N}\right)e^{-sR_0}}{\left(s+\frac{2N}{R_0^2C}\right)\left(s+\frac{1}{R_0}\right)} \quad (7)$$

- Formulate the improved system function

$$\partial(s) = \frac{\frac{C^2C_k e^{-sR_0}}{2N}}{\left(s+\frac{2N}{R_0^2C}\right)\left(s+\frac{1}{R_0}\right)+\frac{C^2C_k e^{-sR_0}}{2N}} \quad (8)$$

- Find the controller C_k using mixed-synthesis design method through MATLAB simulation that can improve the output of the system and satisfy the desired characteristics.
- Apply the weighting functions $W_1(s)$ and $W_2(s)$ on the TCP queue transfer function $G_p(s)$
- Form the augmented function P(s) with Gp(s), $W_1(s)$ and $W_2(s)$ using MATLAB operator, aug:

$$P(s) = aug(Gp, W1, W2) \quad (9)$$

- Generate the controller C_k in state space using the mixsyn syntax in MATLAB:

$$[C_k] = mixsyn(P) \quad (10)$$

- Compute the open loop gain function:

$$L = C_k \times P \quad (11)$$

- Compute the sensitivity function:

$$S = (1 + L)^{-1} \quad (12)$$

- Plot a time graph for the improved system function $\partial(s)$ to determine the settling time, overshoot and steady state error.
- Plot a frequency graph for the improved system function $\partial(s)$ to determine the tracking error.

3.2.4 Simulation Parameters

The simulation parameters for the LTE network congestion improvement is as shown in the table 3.1. The algorithm for the controller design using mixed-synthesis technique is implemented in MATLAB m-file for the TCP queue performance improvement and analysis.

Table 1: Simulation Parameters for the LTE Network [7, 97].

Parameter	Value
Link Capacity, CL	3750 or 4200 packets/s
RTT	0.25s
Server link Bandwidth	100Mbps
Load Factor, N	60
Packet Size	1500 Bytes
Window Size	48 Kbytes
Simulation Time	30 Sec.

3.3 TCP Performance Improvement Using PID Control Method

The PID control method was applied on the TCP over LTE network for improving the performance of the TCP based on the reduction of TCP settling time and the tracking error. PID control method used the three terms, Proportional-Integral-Derivative control functions to compensate or control the error generated from the difference between the actual output and the desired output or reference input. The ability of the controller to reduce this error to zero becomes the major objective of this method.

The PID control transfer function can be expressed as follows:

$$\boldsymbol{C_{kPID}(s) = K_p + \frac{K_i}{s} + K_d s} \tag{13}$$

3.3.1 The PID Control Algorithm Expressed As Follows

- Apply the TCP queue system transfer function:

$$G_p(s) = \frac{\left(\frac{C^2}{2N}\right)e^{-sR_0}}{\left(s+\frac{2N}{R_0^2 C}\right)\left(s+\frac{1}{R_0}\right)} \tag{14}$$

- Formulate the improved TCP queue system model

$$\partial(s) = \frac{\frac{C^2 C_k e^{-sR_0}}{2N}}{\left(s+\frac{2N}{R_0^2 C}\right)\left(s+\frac{1}{R_0}\right)+\frac{C^2 C_k e^{-sR_0}}{2N}} \tag{15}$$

- Find the controller C_k using PID control design method through MATLAB simulation that can improve the output of the system and satisfy the desired characteristics.

- Formulate the loop gain:

$$L = C_k G_p = \frac{C_k \cdot \left(\frac{C^2}{2N}\right)e^{-sR_0}}{\left(s+\frac{2N}{R_0^2 C}\right)\left(s+\frac{1}{R_0}\right)} \tag{16}$$

- Plot a time graph for the improved LTE system function $\partial(s)$ to determine the settling time, overshoot and steady state error.

- Plot a frequency graph for the improved LTE system function $\partial(s)$ to determine the tracking error. The algorithm for the controller design using PID technique is implemented in MATLAB m-file for the TCP queue performance improvement and analysis.

4.0 RESULTS AND ANALYSIS

The analysis results of the TCP based LTE wireless network performance with respect to the data collected is as shown in Figures 5 and 6.

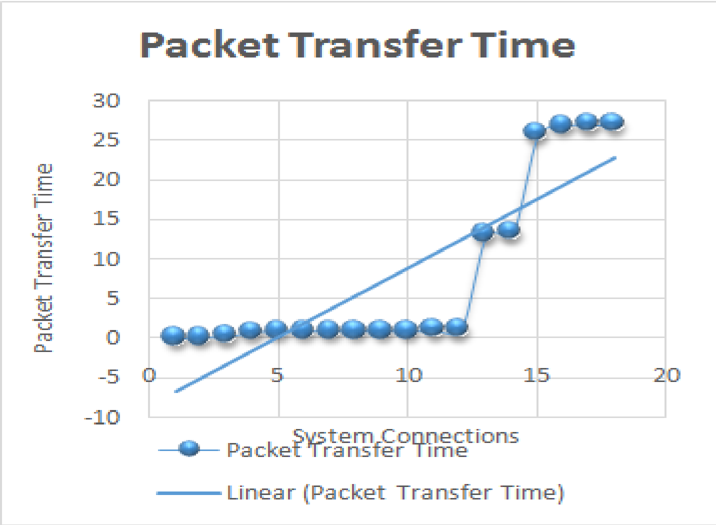

Figure 5: LTE Packet Transfer-Time Result for First Measurement.

The results in Figure 5 show that: The packet transfer time maintained faster data transfer time when the wireless connections were less than 12 system connections. This means that the LTE system experiences faster data transfer when the network traffic is small. The packet transfer time increased when the wireless connections increased more than 12 system connections. This means that the TCP based LTE network system speed been affected when the network data transfer traffic increases. This indicates that the LTE network will suffer from traffic congestion when the network traffic increases with heavy data video and voice. This also shows that the LTE network will run very slowly especially when the network traffic increases.

$$y = 1.732x - 8.529 \quad (17)$$

Equation 4.1 was derived from the straight-line graph of TCP based LTE network packet transfer time results in Figure 4.1.

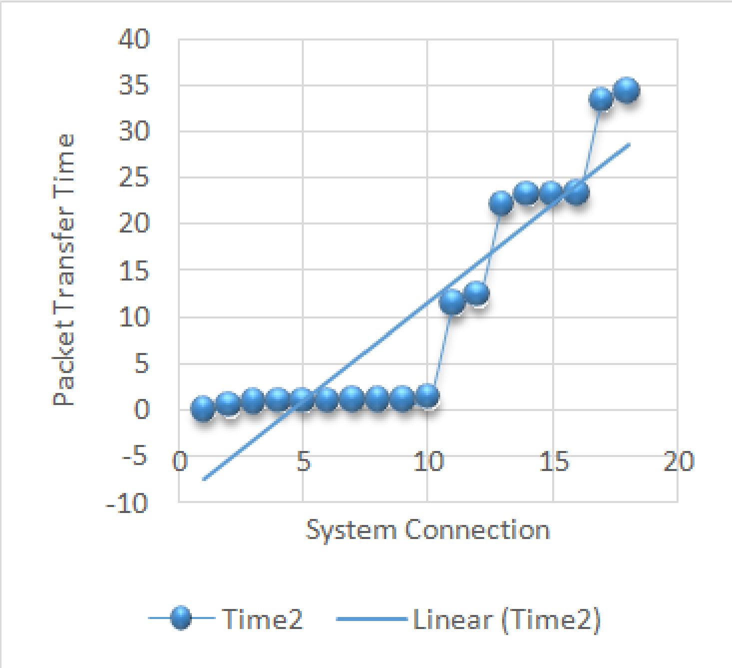

Figure 6: LTE Packet Transfer-Time Result for Second Measurement

The results in Figure 3.2 show that: The packet transfer time maintained faster data transfer time when the wireless connections were less than 10 system connections. This means that the LTE system experiences faster data transfer when the network traffic is small. The packet transfer time increased when the wireless connections increased more than 10 system connections. This means that the TCP based LTE network system speed been affected when the network data transfer traffic increases. This indicates that the LTE network response is very slow when the traffic increases and when the system connections increases.

$$y = 2.1125x - 9.4652 \tag{18}$$

Equation 3.2 was derived from the straight line graph of TCP based LTE network packet transfer time results in Figure 6.

4.1 Modified LTE Network Using Mixed Sensitivity Synthesis

The modified LTE network using mixed sensitivity synthesis shows the improved TCP based LTE network performance based on the damping time of the modified LTE system output response. The compensator that can help to improve the LTE network was developed in experiments by modifying the weighting functions.

4.1.1 Experiment I

This was carried out in two scenarios: when the link capacity $(C_L)$is 3750 packets/seconds and 4200 packets/seconds using the weighting functions as expressed as follows:

For link capacity C=3750 packets/seconds, the plant model been:

$$G_P = \frac{25310000000}{s^2+4.002s+0.008} \tag{19}$$

For link capacity C=4200 packets/seconds, the plant model been:

$$G_P = \frac{31750000000}{s^2+4.002s+0.007143} \tag{20}$$

$$W_1 = \frac{1000(0.001s+10)}{s+10} \tag{21}$$

W_1 Been weighting function model at the error signal (e).

$$W_2 = tf\left(\frac{1}{0.1}\right) \tag{22}$$

W_2 Been weighting function model at the control signal (u).

4.1.2 First Scenario of Experiment I, When C=3750 Packets/Seconds

$$C_{k11} = \frac{310317.5S^2+386988.866S+2245222.99eS-266.27e^2+2644667.3e-463130.61}{15+1.5S+0.8579eS+8.5788e} (4.7)$$

The first scenario of experiment I was carried out using TCP based LTE network link capacity of 3750 packets/seconds:

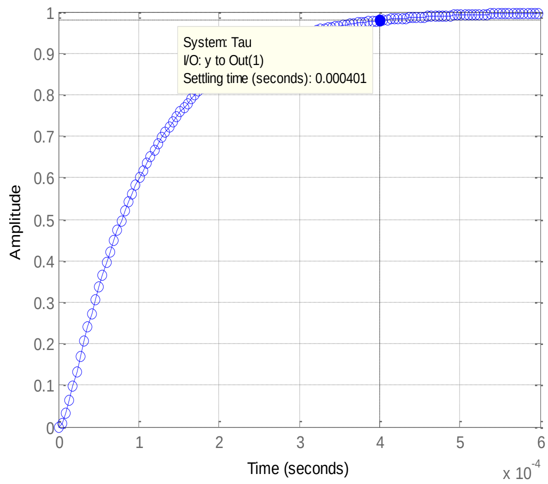

Figure 7: The Time Response of LTE Network When C=3750 Packets/Seconds

The results in Figure 3.3 show that: The modified LTE network achieved damping time of 0.000401 seconds. This means that the modified LTE network using mixed sensitivity synthesis achieved a faster system. This indicates that the modified LTE network will cancel the traffic congestion within 0.000401 seconds.

4.2.3 Second Scenario of Experiment 1, When Link Capacity is 4200 Packets/Seconds

$$C_{K12} = \frac{1370247S^2-9516596.6S+4730298.61eS-643.4e^2+643660.96e-1111112.92}{S^3+03S^2-70.8125S+3.418eS^2+34.6495eS-12.8206} \tag{23}$$

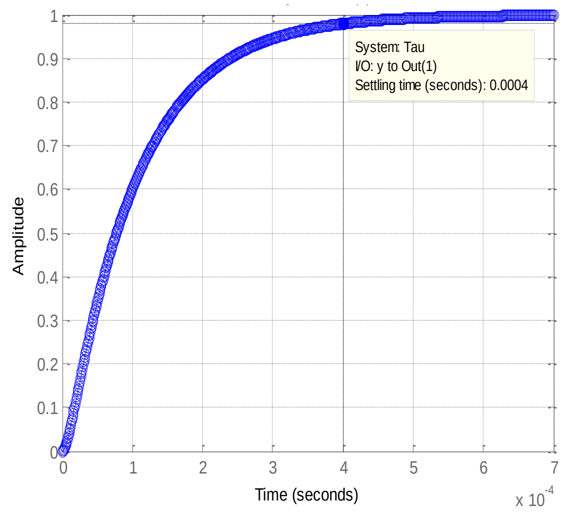

Figure 8: The Time Response of LTE Network When C=4200 Packets/Seconds

The results in Figure 3.4 shows that: The modified LTE network achieved damping time of 0.0004 seconds. This means that the modified LTE network using mixed sensitivity synthesis achieved a faster system. This indicates that the modified LTE network will take 0.0004 seconds to cancel the traffic congestion.

The developed compensator C_{K12} using mixed sensitivity synthesis for the second experiment with link capacity C_{L12} of 4200 and weighting functions in Equations 4.5 and 4.6 as expressed in state space format as follows:

4.3.1 Experiment II

This was carried out in two scenarios: when the link capacity is 3750 packets/seconds and 4200 packets/seconds using the weighting functions as expressed as follows:

For link capacity C=3750 packets/seconds, the plant model been:

$$G_P = \frac{25310000000}{s^2+4.002s+0.008} \tag{24}$$

For link capacity C=4200 packets/seconds, the plant model been:

$$G_P = \frac{31750000000}{s^2+4.002s+0.007143} \tag{25}$$

$$W_1 = \frac{1000(0.001s+10)}{s+10} \tag{26}$$

W_1 Been weighting function model at the error signal(e).

$$W_2 = tf\left(\frac{1}{0.01}\right) \tag{27}$$

W_2 Been weighting function model at the control signal (u).

The first scenario of experiment I was carried out using TCP based LTE network link capacity G_L3750 packets/seconds and 4200 packets/seconds respectively:

4.3.2 First Scenario Of Experiment II, When C=3750 Packets/Seconds

$$C_{k21} = \frac{10376S^2+60364.28S-12659.14eS+3790.90e^2+118.33e-10421.54}{1.375S-0.36525eS-3.6525e+13.75} \tag{28}$$

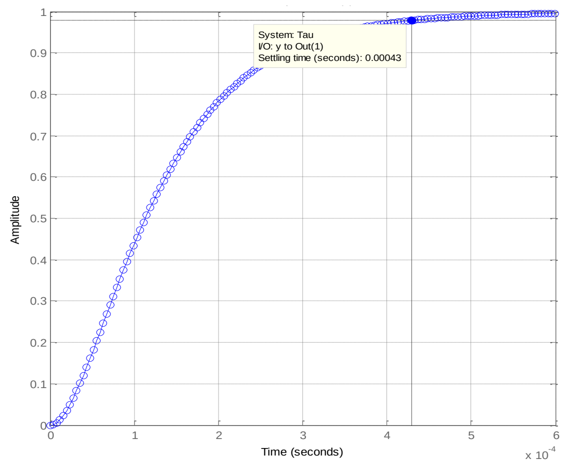

Figure 9: The Time Response Of LTE Network When C=3750 Packets/Seconds

The results in Figure 3.5 show that: The modified LTE network achieved damping time of 0.00043 seconds. This means that the modified LTE network using mixed sensitivity synthesis will achieve a fast packet transfer. This indicates that the modified LTE network will take 0.00043 seconds to cancel the traffic congestion.

The developed compensator C_{k21} using mixed sensitivity synthesis for the first experiment with link capacity of 3750 packets/seconds and weighting functions in Equations 4.11 and 4.12 expressed in state space as follows:

4.3.3 Second Scenario of Experiment II, When C=4200 Packets/Seconds

$$C_{K22} = \frac{13496360S^2-8.575486.5S+21280430.4eS-785.8e^2+7872972.37e-9343691.25}{S^3+04S^2+60S+16.2289eS+1.565eS^2+5.7889} \tag{29}$$

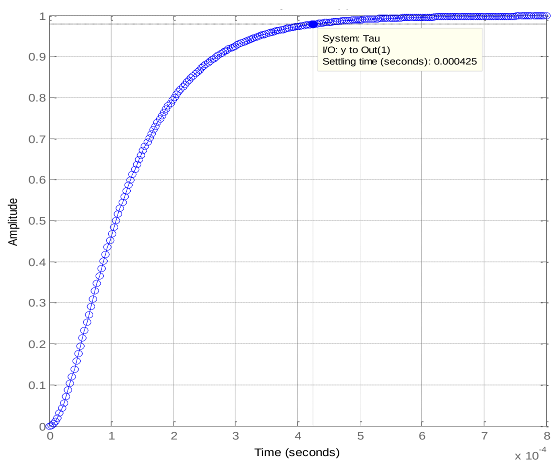

Figure 10: The Time Response of LTE Network When C=4200 Packets/Seconds

The results in Figure 4.6 show that: The modified LTE network achieved damping time of 0.000425 seconds. This means that the modified LTE network using mixed sensitivity synthesis will achieve a fast packet transfer. This indicates

that the modified LTE network will take 0.000425 seconds to cancel the traffic congestion.

The developed compensator C_{K22} using mixed sensitivity synthesis for the second experiment with link capacity of 4200 packets/seconds and weighting functions in Equations 4.9 and 4.10 expressed in state space format as follows:

The results in Table 2 show that; The first experiment recorded lowest damping time which indicates faster time. However, the first scenario of experiment I recorded the highest error of 3.07dB which is too high for the network. The difference between the error levels of the first and second scenarios of the first experiment is also high which shows that the system is not robust. This is because a robust system maintains close range of output behavior even when there is change or variation in its parameter value. The second experiment of the LTE network improvement recorded 0.00043seconds and 0.000425 seconds in the first and second scenarios respectively when link capacity is 3750 packets/seconds and 4200 packets/seconds. The second experiment of LTE network recorded error of 1.14dB and 1.07dB for first and second scenarios respectively. This means that the LTE network improvement using mixed sensitivity synthesis maintained good and close range performance parameter values which indicate that it achieved better performance and robustness than the first experiment.

4.4. TCP over LTE Network Performance using PID Control

The LTE network modification for performance improvement using PID control technique which is termed TCP-PID based LTE network model was carried out in two scenarios: when the link capacity is 3750 packets/seconds and 4200 packets/seconds.

4.4.1 First Scenario - when C=3750 packets/seconds

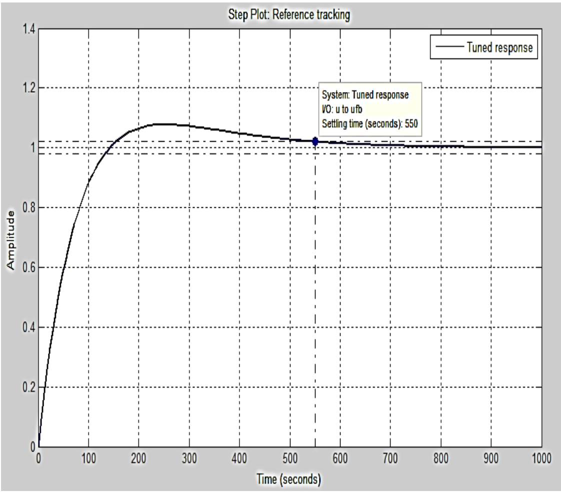

Figure 11: The Time Response of for TCP-PID Based LTE Network When C=3750 Packets/Seconds

The results in Figure 11 show that: The modified LTE network achieved damping time of 550 seconds. This means that the modified LTE network using PID control technique achieved a slower system. This indicates that the modified LTE network will cancel the traffic congestion within 550 seconds. The damping time recorded by the TCP-PID based LTE network is very high. This can cause significant loss of data because the slow nature of the network will suffer from high traffic congestion, which will affect the performance of the network.

The parameters of the developed compensator Ck using PID control technique for the first scenario with link capacity of 3750 packets/seconds is expressed in Table 4.2 as follows:

Table 3: The PID Controller Parameters

PID Parameter	Value
K_p	1.5357e-10
K_i	7.6607e-13
K_d	0

4.4.2 Second Scenario - When C=4200 Packets/Seconds

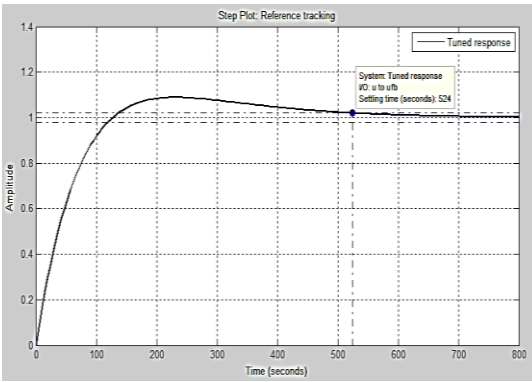

Figure 12: The Time Response of for TCP-PID Based LTE Network When C=4200 Packets/Seconds

The results in Figure 4.18 show that: The modified LTE network achieved damping time of 524 seconds. This means that the modified LTE network using PID control technique achieved a slower system when link capacity is 4200 packets/seconds. This indicates that the modified LTE network will cancel the traffic congestion within 524 seconds. The damping time recorded by the TCP-PID based LTE network is also very high. This can cause significant loss of data because the slow nature of the network will suffer from high traffic congestion, which will affect the performance of the network.

Table 4: The PID Controller Parameters for Second Scenario.

PID Parameter	Value
K_p	1.3177e-10
K_i	7.004e-13
K_d	0

CONCLUSIONS

The LTE network model performance improvement was carried out using mixed sensitivity synthesis which is a robust control technique, which uses three adjustable weighting functions implemented by the mixsyn command to develop a

compensation function that is used to modify the TCP based LTE network model. The LTE network improvement was also carried out using PID control technique with three control functions such as proportional, integral and derivative to improve the system. The LTE network improvement using mixed sensitivity synthesis recorded damping time of 0.00043 seconds and 0.00042 seconds when the link capacity is 3750 packets/second and 4200 packets/second respectively. While the LTE network improvement using PID control technique recorded damping time of 550 seconds and 524 seconds when the link capacity is 3750 packets/second and 4200 packets/second respectively. The LTE network improvement using mixed sensitivity synthesis achieved better damping time than PID control technique. This indicates that the mixed sensitivity synthesis will address traffic congestion issue better than the PID control technique.

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